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PRE-EXERCISE CARBOHYDRATE ADMINISTRATION: EFFECT OF TIMING ON THE RATE OF GLYCOGEN METABOLISM DURING SUBMAXIMAL RUNNING

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Abstract:
The aim of this study was to investigate the metabolic responses of the timing of preexercise carbohydrate feeding. Nine moderately trained runners, 7 men, and 2 women, performed an incremental test to exhaustion followed by three 6 min running trials at 75% VO_2max on the treadmill. The submaximal runs were performed after ingestion a placebo solution (PLA) one hour before or CHO solution 1gr.kg$_{BM}^{-1}$ one (CHO60) or two hours (CHO120) before the trial. All trials were performed at least 2 days apart in a double-blind cross-over design following an overnight fast. The results showed no significant differences in physiological parameters (VO_2, RER, HR) and CHO metabolism between the three conditions. Blood glucose concentration immediately before the 6-min trials was higher after CHO60 (1.22±0.23 gr.L^{-1}) compared to CHO120 (0.93±0.10 gr.L^{-1}) conditions ($p=0.007$, $\eta^2= 0.567$). These findings suggest that preexercise timing of CHO ingestion results in significantly different blood glucose concentrations prior to submaximal running, with no further metabolic and physiological alterations.

Keywords: carbohydrates, physiological parameters, metabolic responses

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1. Introduction

It is well established that muscle glycogen availability is highly related to performance and fatigue in prolonged submaximal exercise (18, 21). It is proposed to consume 1-4 $gr.kg_{BM}^{-1}$ of carbohydrates (CHO) 1-4 h before an endurance event, in order to provide high CHO availability and maximize endurance performance (5). Therefore, the timing of CHO injection is one of the most crucial elements in order to avoid endurance performance decrements due to limited CHO availability. Several studies have shown that when CHO is consumed within the hour before an endurance trial, blood glucose, blood insulin concentration, and RER values increase, reduce liver glucose output as well as increase glucose metabolism, and induce exercise hypoglycemia at the onset of the exercise. Blood glucose and blood insulin return to their baseline values during the initial minutes of the exercise (6, 8, 16, 19, 28, 29). When CHO is consumed during warm-up, symptoms of hypoglycemia do not appear (4). Despite these findings, endurance performance is either enhanced (1, 31, 34, 35) or not affected (6, 8, 16, 19, 28) after CHO injection. Only Foster et al. (13) have found a performance decrease after CHO injection, accompanied by a significant increase in CHO oxidation and a decrease in free fat acid activation.

Carbohydrates injection 30, 60 or 90 min prior to endurance running did not affect time to exhaustion (TTE), but in order to maintain normoglycaemia CHO should be consumed up to 30 min prior to running (36). In most studies, TTE or mean power in cycloergometer was not affected when CHO was consumed in different time periods prior to endurance exercise (29, 32, 33). Only Galloway et al. (14) found significantly higher TTE when CHO was injected 30 min compared to 120 min prior to a 90% PPO cycling trial. Pritchett et al. (32) did not report alterations in metabolic responses when CHO was injected 15 or 60 min prior to exercise, although, in other studies, higher plasma glucose and plasma insulin concentration were observed when the timing of the CHO injection is closer to the onset of the exercise (29, 33). These metabolic responses are eliminated during the first 10 min of the exercise (29). Values of RER, CHO, and fat metabolism, were not affected after administration of CHO 1, 2, 3, or 4 hours prior to cycling endurance exercise (33).

The purpose of the present study was to investigate the metabolic and physiological effects of carbohydrate administration ($1gr.kg_{BM}^{-1}$ glucose) 1 and 2 hours prior to submaximal endurance running (75% VO_2max).

2. Methods

2.1 Participants

Nine moderately trained runners (7 men and 2 women) volunteered to participate in the present study (Table 1). The subjects were physically active (trained at least 3 times/week) and had no recent injury, nor received any medication. All individuals were informed of the nature, purpose, and potential risks, and benefits of the study before giving their

written consent. The study was approved by the Ethics Committee of the National and Kapodistrian University of Athens and was conducted according to the guidelines of the declaration of Helsinki II. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (30).

Table 1: Anthropometrical characteristics (mean±sd, n=9).

	Mean±sd
Age (yr)	35.56 ± 14.91
Body mass (kg)	70.07 ± 7.65
Body fat (%)	16.56 ± 6.17

2.2 Protocol

The subjects performed 4 laboratory visits, at least 2 days apart. During the first visit after anthropometrical measures, the subjects underwent an incremental test to exhaustion on a treadmill, after a 6 min warm-up and a 5 min stretching routine. The velocity was increased by 1 $km.h^{-1}$ every 2 min until exhaustion, while the gas collection was performed during the last 60 s of each stage, in order to attain steady state VO_2, using the open circuit Douglas bag method (25). On Visits 2-4, the subjects performed a 6 min trial on the treadmill at a velocity corresponding to their individual 75% vVO_2max, under three different conditions in random order. The subjects consumed either 250 ml of a flavored water solution (Placebo-PLA) 1 hour before the 6 min trial, or 1 $gr.kg_{BM}^{-1}$ of glycose dissolved in 250 gr water also 1 hour before the 6 min trial (CHO60) or identical glucose solution 2 hours (CHO120) before the 6min trial. Body mass was measured each time before the 6 min trial, in order to determine the amount of glucose intake. Blood glucose levels were measured immediately before the 6 min trials, while during the 6min trials HR, VO_2 and RER were recorded. All trials were performed in the morning (8 p.m. – 9 p.m.), after a 10-hour fast, in stable environmental laboratory conditions, while all subjects were asked to repeat the same diet and activity pattern for 24 hours preceding each visit.

Anthropometric measurements included body height to the nearest mm (Seca Leicester, U.K.), body mass to the nearest 0.01 kg (Seca 710, U.K.), and body fat percentage calculation (Harpenden, U.K.). The body fat percentage was calculated using the thickness of the biceps, triceps, suprailiac, and subscapular skinfolds (9). Respiratory gases were measured using the Douglas bag method. The subjects breathed through a low resistance 2-way Rudolph 2700 B valve. The expired gases passed through a 90 cm length of 340 mm diameter flexible tubing into a 200-litre capacity Douglas Bag. The concentration of CO_2 and O_2 in the expired air was measured by using the Hitech (GIR 250) combined Oxygen and Carbon Dioxide Analyzer. The gas analyzers were calibrated continuously against standardized gases (15.88% O_2, 3.95% CO_2, and 100% N_2). Expired volume was measured by means of a dry gas meter (Harvard) previously calibrated against a standard airflow with a 3-litre syringe, while barometric pressure and gas temperature were constantly recorded. Respiratory gas exchange data for each workload

(i.e. VO_2, VCO_2, VE, and RER) were determined on a locally developed computer program based on the computations described by McArdle, Katch, and Katch (27) when VEatps, $FECO_2$, and FEO_2 are known. The highest VO_2 value obtained during an incremental exercise test was recorded as the subject's VO_2max, which also elicited a heart rate within ±10 bpm of age-predicted HRmax, a respiratory exchange ratio (RER) greater than 1.05 and finally a score on the completion of the test equal to or greater than 18 on 6-20 Borg scale (3). The velocity at VO_2max (vVO_2max) was determined as the lowest running velocity that elicits a VO_2 equivalent to VO_2max during the incremental test to exhaustion (2). The heart rate (HR) was recorded every 5 s throughout the exercise tests using short-range telemetry (Polar S 710, Polar, Helsinki, Finland). Fingertip blood samples were taken immediately before the 6 min trials for the determination of glucose levels. All tests were checked for validity and reliability.

2.3 Statistical Analysis

All data are presented as mean ± standard deviations. The normality of the data distributions was tested by the Kolmogorov-Smirnov test, while sphericity was tested by Mauchly's Test of Sphericity. Separate one-way repeated-measures ANOVAs were performed to determine any differences between the three conditions. In case of significance, the Bonferroni post-hoc test was conducted. The significance level was set at $p<0.05$. All the analyses were performed using the IBM SPSS Statistics 23.

3. Results

Table 2 shows the subjects' cardiorespiratory endurance characteristics (mean±sd). There was a significant difference in blood glucose levels prior to the 6min between the three conditions ($p=0.007$, $\eta^2= 0.567$, Figure 1). This difference was focused on between CHO60 and CHO120 conditions (GLU60=1.22±0.23 vs GLU120=0.93±0.10, $p=0.009$). No further significant differences were observed between the three conditions (Table 3).

Table 2: Cardiorespiratory endurance characteristics (mean±sd, n=9).

Parameter	Participants
VO_2max ($ml.kg^{-1}.min^{-1}$)	52.74±9.32
vVO_2max ($km.h^{-1}$)	16.67±2.05
HRmax (bpm)	184.4±12.7
VEmax ($L.min^{-1}$)	107.19±22.99

Table 3: Physiological and metabolic characteristics under the three conditions (mean±sd, n=9)

Parameter	PLA	CHO60	CHO120	p	Partial η^2
CHO ($g.min^{-1}$)	2.11±0.79	2.46±0.79	2.25±1.21	0.162	0.204
HR (bpm)	151.22±16.42	148.22±28.31	149.11±15.89	0.651	0.034
VO_2($ml.kg^{-1}.min^{-1}$)	41.25±6.45	41.34±7.97	41.87±6.77	0.619	0.058
RER	0.89±0.05	0.92±0.06	0.89±0.08	0.088	0.262
GLU ($gr.L^{-1}$)	1.01±0.05	1.22±0.23	0.93±0.10	0.007	0.567

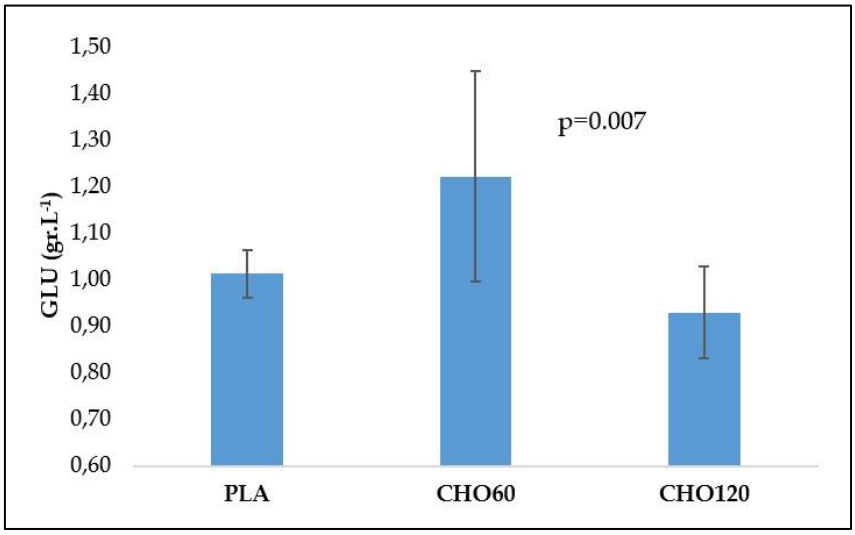

Figure 1: Glucose concentration prior to the 6-min trial (75%vVO2max) under the three conditions (mean±sd, n=9)

4. Discussion

The main finding of the study was the increased blood glucose concentration after the administration of 1gr.kg$_{BM}^{-1}$ 1 hour prior to submaximal endurance running (75% VO2max) compared to consuming the same amount of CHO 2 hours prior to running (p=0.009). It seems that one or two hours before submaximal exercise CHO supplementation didn't affect the response of VO2, HR, RER, and CHO metabolism.

The results of the present study are in agreement with published similar research. When CHO was ingested 45 min prior to cycling in 75% VO2max, VO2, HR and RER remained unchanged (16), while the results were similar when 75 gr of glucose were consumed 1 h prior to cycling in 71% VO2max (26). Similarly, Moseley et al. (29) and Sasaki et al. (33) reported no significant differences in physiological parameters when CHO was consumed at several different timings prior to submaximal cycling. In other studies, glucose ingestion 15 min (35) and 30 min (6) prior to submaximal running also did not affect the examined physiological parameters. Although, not all studies are in agreement with these findings. McMurray et al. (28) reported lower VO2 and higher RER in submaximal running after glucose administration, compared to placebo, most likely due to higher CHO utilization. Moreover, Tokmakidis and Volaklis (36) found that after CHO prefeeding in different timings prior to running, lactate concentration and VO2 were significantly lower compared to placebo, while HR was not affected, while Sherman et al. (34) found significantly higher HR and RER compared to placebo, with no differences in VO2.

Immediately prior to the onset of the submaximal endurance running the blood glucose concentration was significantly different between the three conditions (p=0.007, η^2= 0.567). The majority of the existing literature is in accordance with our findings, since many studies have reported significantly higher blood glucose levels when CHO is

consumed up to 60 min prior to endurance exercise compared to placebo condition (6, 7, 15, 16, 26, 28, 35, 36). It is also well established that the closer to the onset of the exercise the CHO is consumed, the higher the blood glucose levels are (29, 36), or tend to be (33). A common phenomenon in pre-exercise carbohydrate feeding is "rebound hypoglycaemia" (20). During this phenomenon, CHO injection up to 60 minutes prior to endurance exercise causes hyperglycemia and hyperinsulinemia, followed by a sharp decrease in blood glycose concentration at the onset of the exercise (7, 13, 17, 24). Despite the fact that rebound hypoglycemia is frequently observed, it is not reported in all cases or in all subjects (6, 15, 16, 23, 26, 28). In our study, blood glucose concentration is significantly higher in CHO60 compared to CHO120 and tends to be higher than PLA. This is an indication that 2 hours after CHO consumption, glucose levels have returned to values similar to placebo values, while 1 hour after CHO consumption higher blood glucose concentration is reported.

In many studies, pre-exercise CHO ingestion leads to increased CHO usage during submaximal running (7) and cycling (11, 13, 17, 22, 24) exercises. In our study, there was no significant difference in CHO metabolism during the 6 min submaximal running trial between the three conditions. These findings are in accordance with several studies (6, 10, 12, 15, 16, 28, 34), as the total amount of CHO oxidized does not seem to be affected by pre-exercise feeding. Since CHO metabolism is similar between the conditions it is unlikely to induce early fatigue and adversely affect prolonged submaximal endurance performance.

In conclusion, the data of the present study showed that CHO60 compared to CHO120 and PLA increased blood glucose concentration prior to exercise. VO_2, HR, RER, and CHO metabolism during submaximal endurance running (75% VO_2max) were not affected, indicating that CHO consumption 1 or 2 hours unchanged submaximal exercise substrate metabolism.

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Conflict of Interest Statement
The authors declare no conflicts of interest.

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